

12.540 Principles of the Global
Positioning System
Lecture 09

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<http://geoweb.mit.edu/~tah/12.540>

Summary

- Review:
 - Examined definitions of pseudorange and carrier phase
 - Looked at some actual raw measurements from a RINEX file
- Today we look at:
 - Combinations of range and phase measurements
 - Simple differences between observed and rough calculation of expected range and phase measurements
 - Sources of GPS data

Range and phase data

- As we have seen, with real data there are drops out of data (missing data) and often associated with this cycle slips in the phase data.
- The difference between the L1 and L2 range measurements reflects noise and the ionospheric delay (grew by 5 meters in the hour of data we looked at)
- Difference between L1 and L2 phase, when converted to distance using standard frequencies and speed of light, also reflects noise (much smaller than range) and ionospheric delay but with opposite sign to range ionospheric delay.
- This difference can be used to check for cycles slips independent of ionosphere and movement of receivers. Called the Melbourne-Wubena Wide Lane

Melbourne-Wubena Wide Lane

- The difference between L1 and L2 phase with the L2 phase scaled to the L1 wavelength is often called simply the widelane and used to detect cycle slips. However it is effected fluctuations in the ionospheric delay which in delay is inversely proportional to frequency squared.
- The lower frequency L2 has a larger contribution than the higher frequency L1
- The MW-WL removes both the effects on the ionospheric delay and changes in range by using the range measurements to estimate the difference in phase between L1 and L2

Melbourne-Wubena Wide Lane (MW-WL)

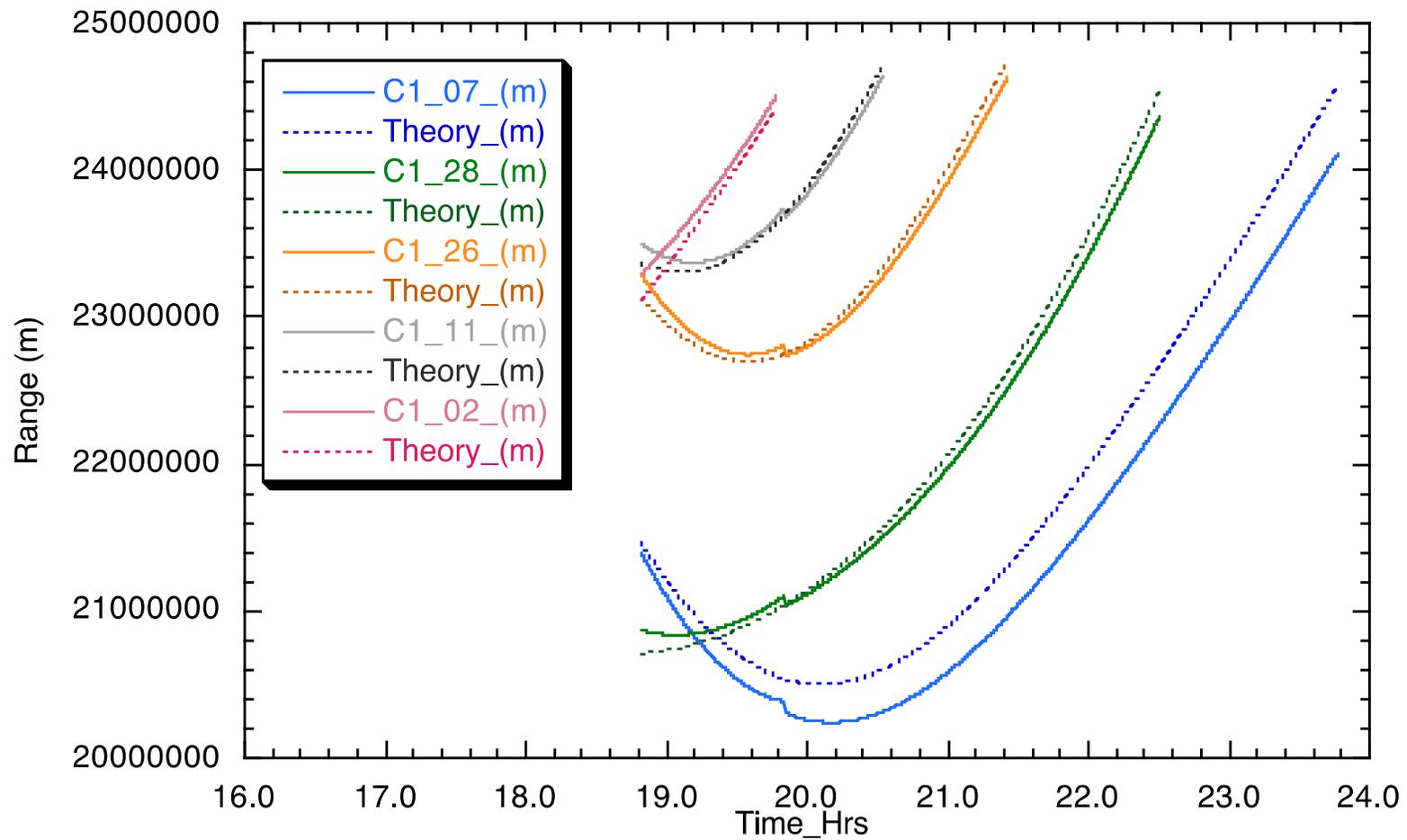
$$mw - wl = \phi_1 - \phi_2 - \frac{(f_1 - f_2)}{(f_1 + f_2)} [R_1 f_1 / c + R_2 f_2 / c]$$

- Equation for the MW-WL. The term Rf/c are the range in cycles (notice the sum due to change of sign ionospheric delay)
- The $\Delta f / \Sigma f$ term for GPS is ~ 0.124 which means range noise is reduced by a about a factor of ten.
- Because of phase and biases range biases, the MW-WL should be integer (within noise) when data from different sites and satellites (double differences) are used. (Example shown later)

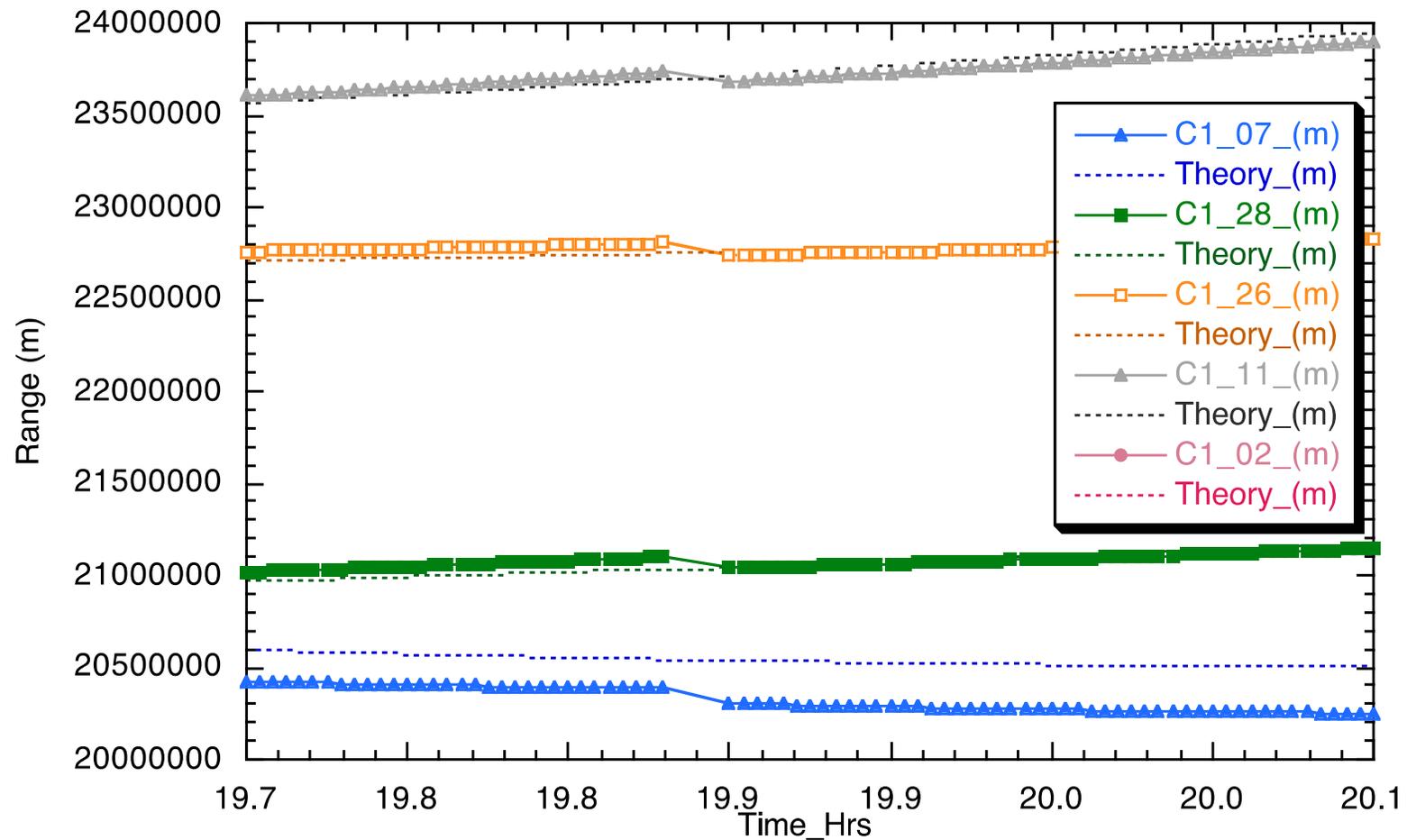
Simple mathematical model

- We know examine as series of results based on the results you are generating for GPS station.
- How closely can the observed ranges and phases be matched with a simple calculation?
- Simplest calculation: At the time given in the rinex data files, compute the position of satellite and based on rinex header position compute the range. How accurate is this?

Direct comparison



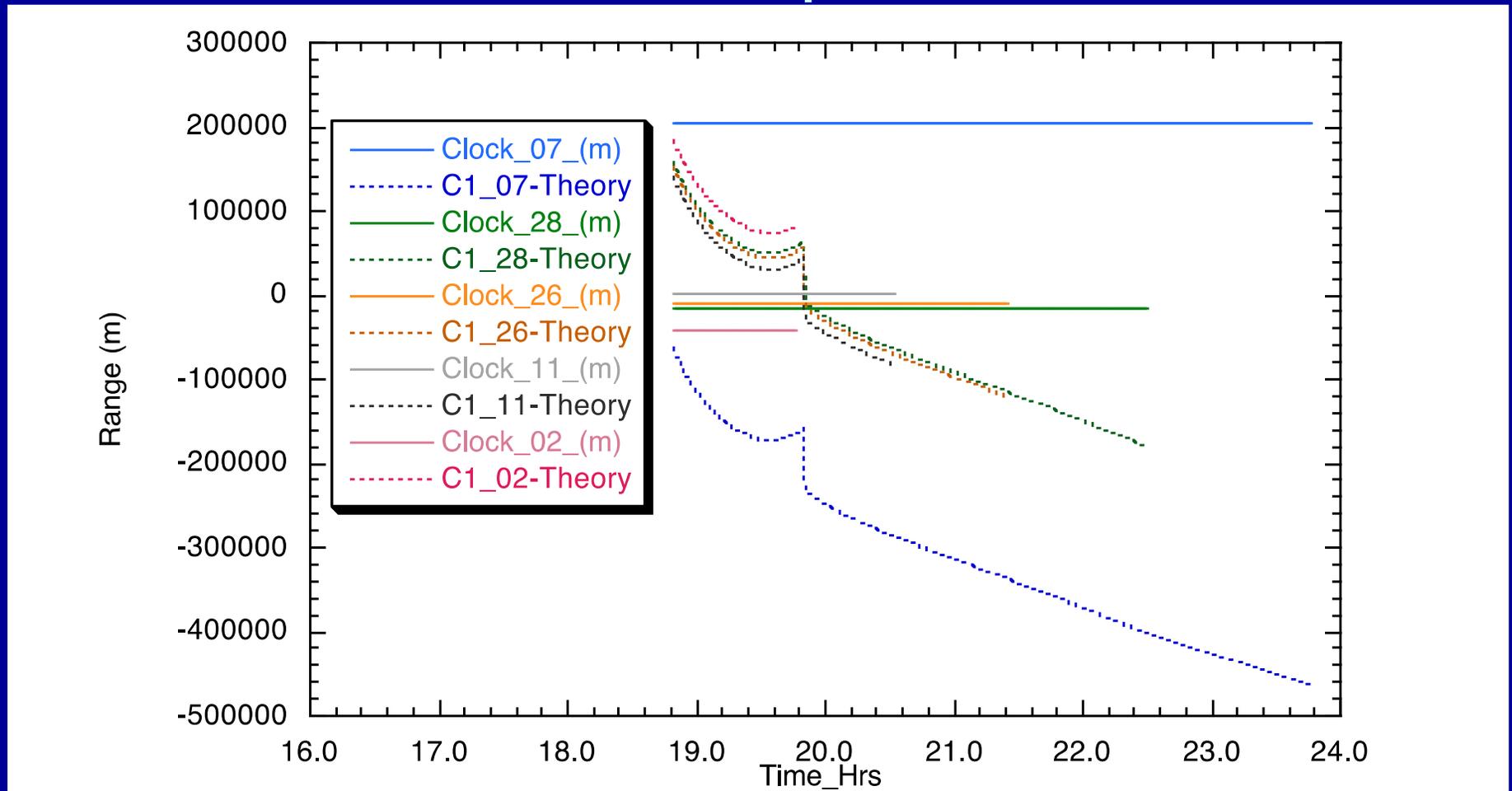
Zoom of “jump” section



C1 range to theory comparison

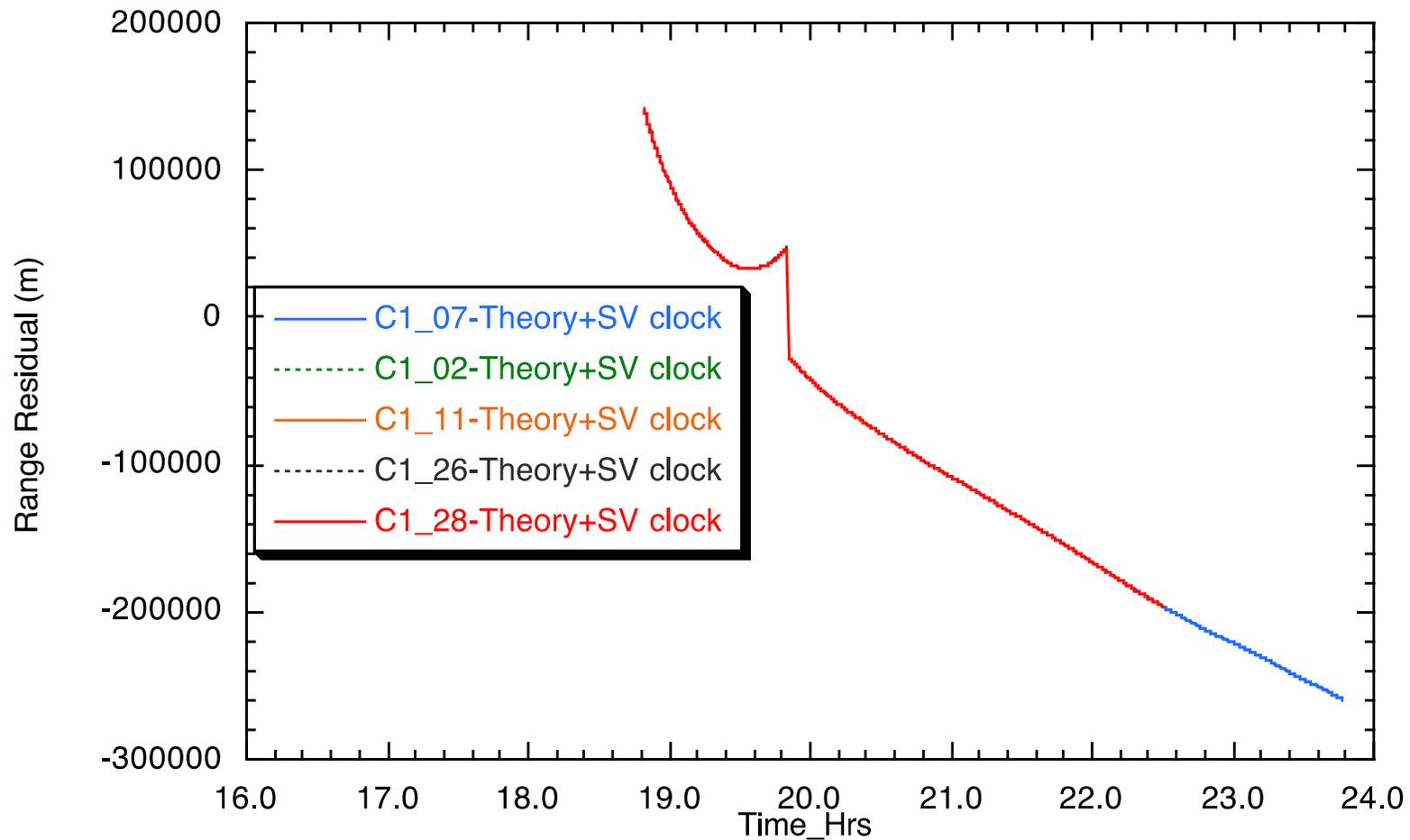
- Clearly the theoretical range and observed ranges are “sort-of” tracking each other but there are large differences.
- The “jump” with missing data seems to show the same jump for all satellites (difficult to tell at this scale) (Class notes have data files, so you can check).
- Pseudorange is difference of clock times, but we have not taken into account the clocks.
- Examine the difference between observed and theoretical range (omc).

Observed - Theory, Clock values from broadcast ephemeris

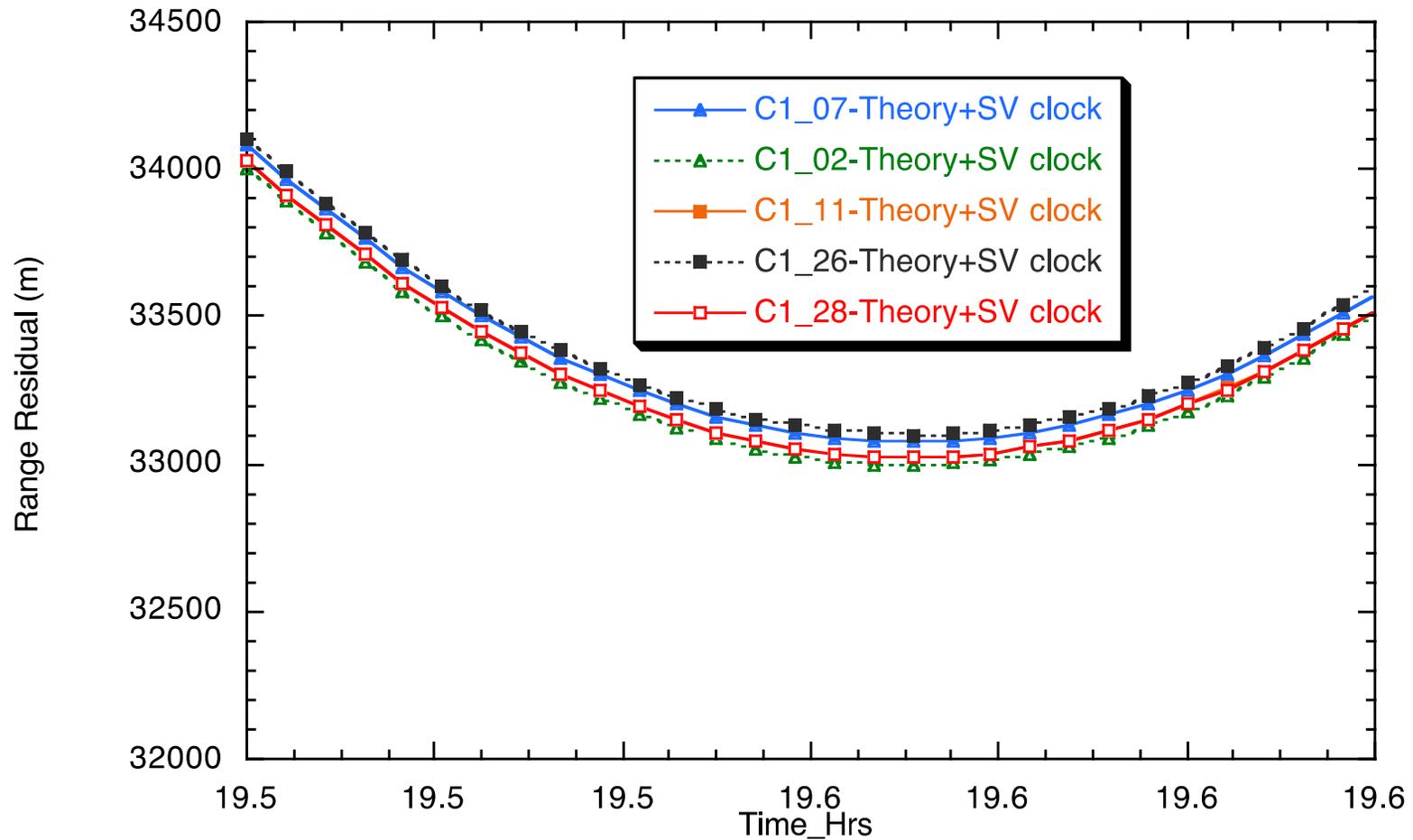


Notice that omc is opposite to clock, Next plot satellite clock corrections added

Observed - theory + satellite clock



Zoom of last plot



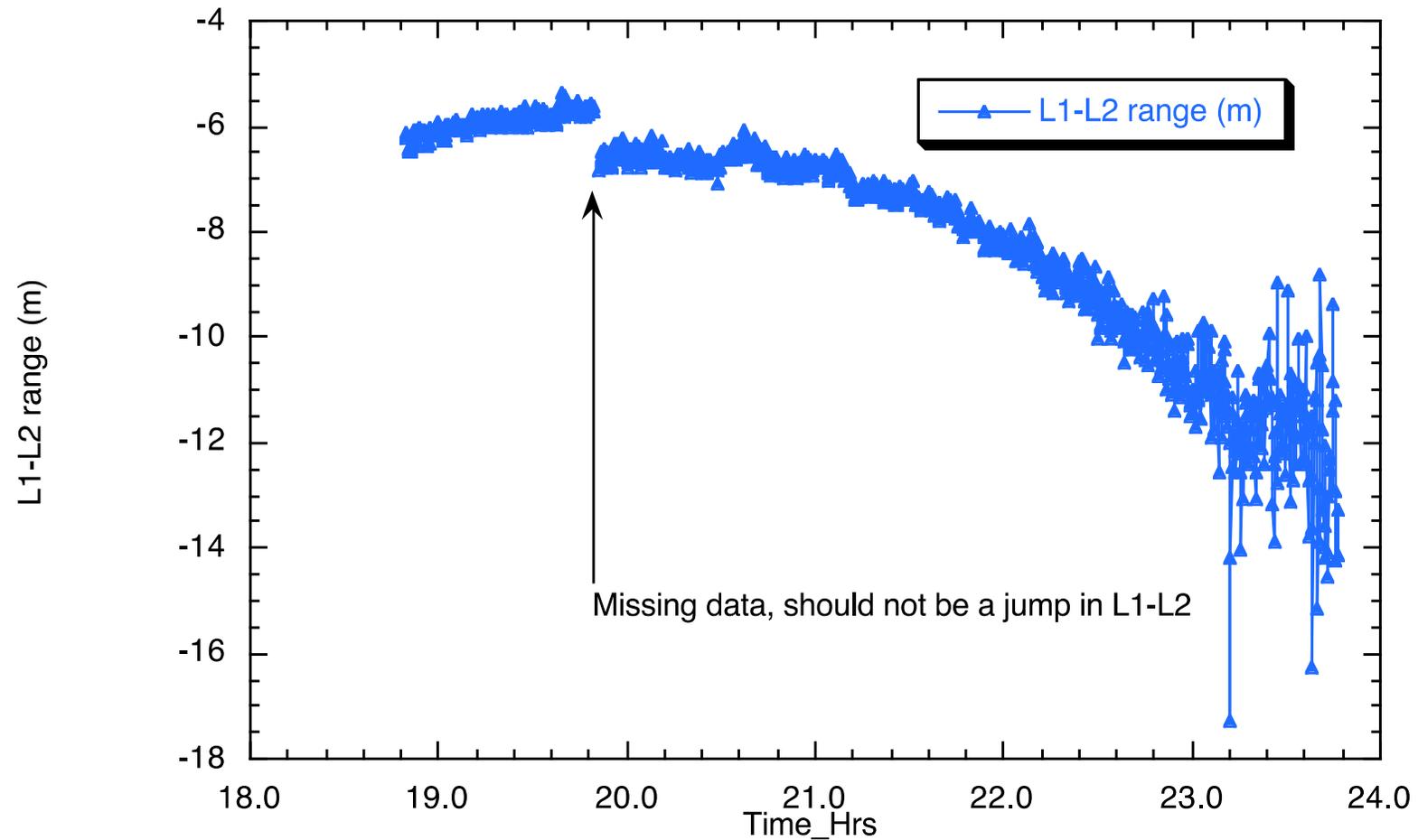
Residuals

- After correcting for the satellites, the large fluctuations can be removed with the receiver clock. Once this is done the remaining residuals are 10-100 meters.
- What needs to be corrected at this point?

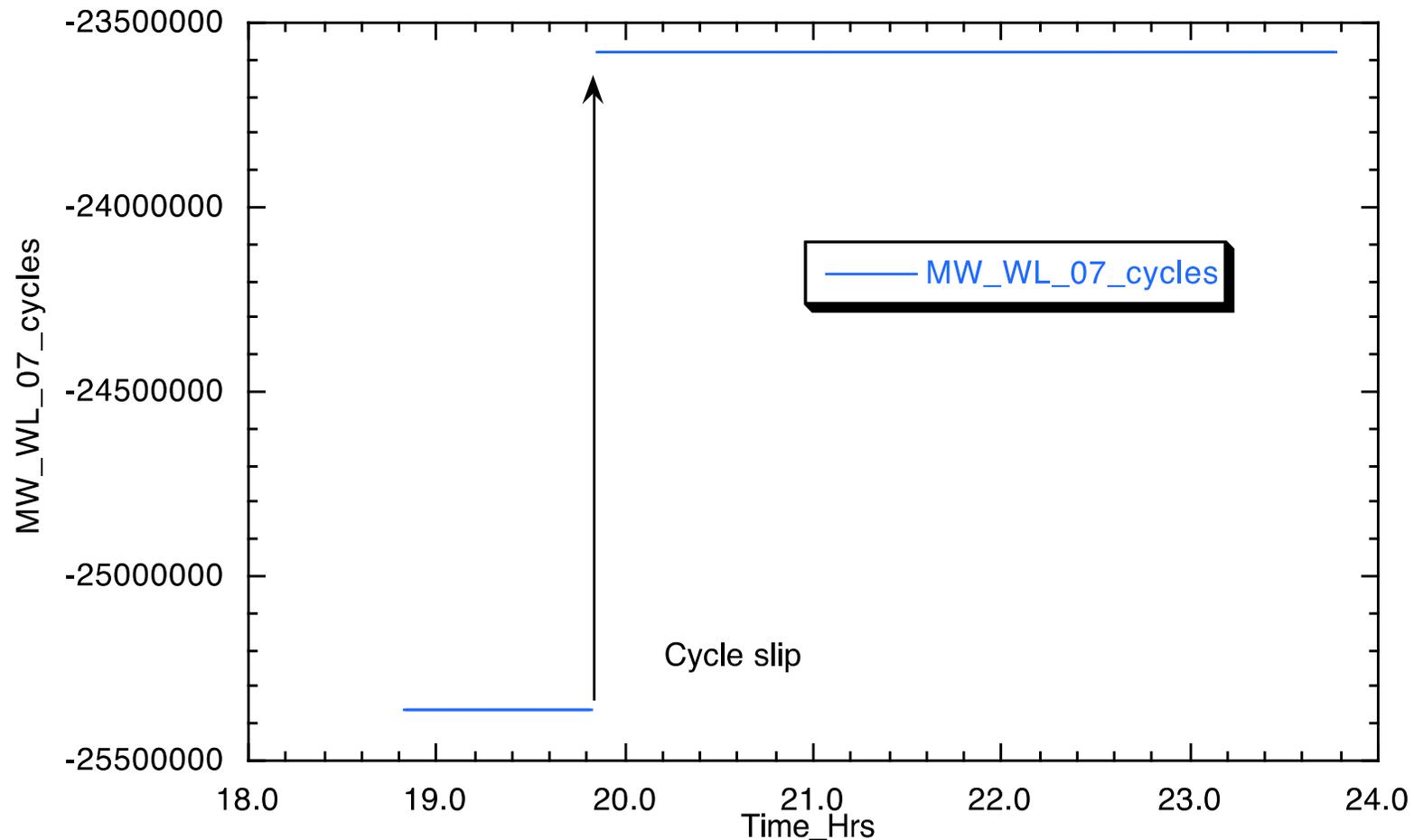
Main model parts missing

- We already saw that L1-L2 range values change by up to 5m for the short span we looked at Monday (next page shows longer segment).
- Errors in station coordinates could add 5-10 m of error depending on quality
- Atmospheric delays (and 3-10 m, especially for low elevation satellites)
- Time the satellite position is calculated: We assumed the time tag on the rinex file but clearly in error by 0.1 msec due to receiver clock. A bigger error is the light propagation time (~7 msec).
- Satellites move in radial direction at ~1km/sec, therefore 7 ms translates to about 7 meters of range change. Later in course you will need to do this calculation

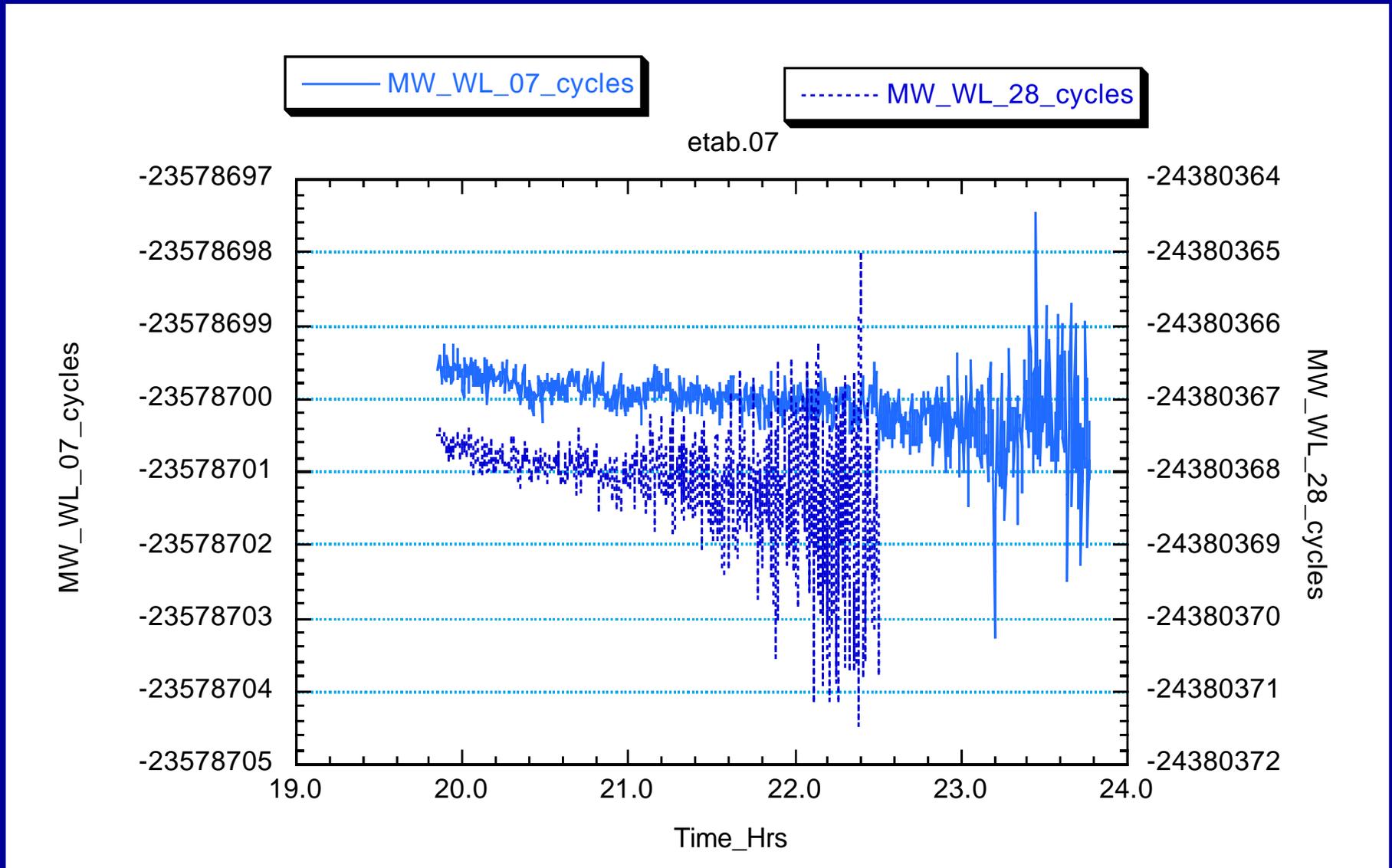
L1-L2 range for PRN 07



MW-WL (used for detecting cycle slips and resolving phase ambiguities)



MW-WL Last part of data (plus PRN 28)



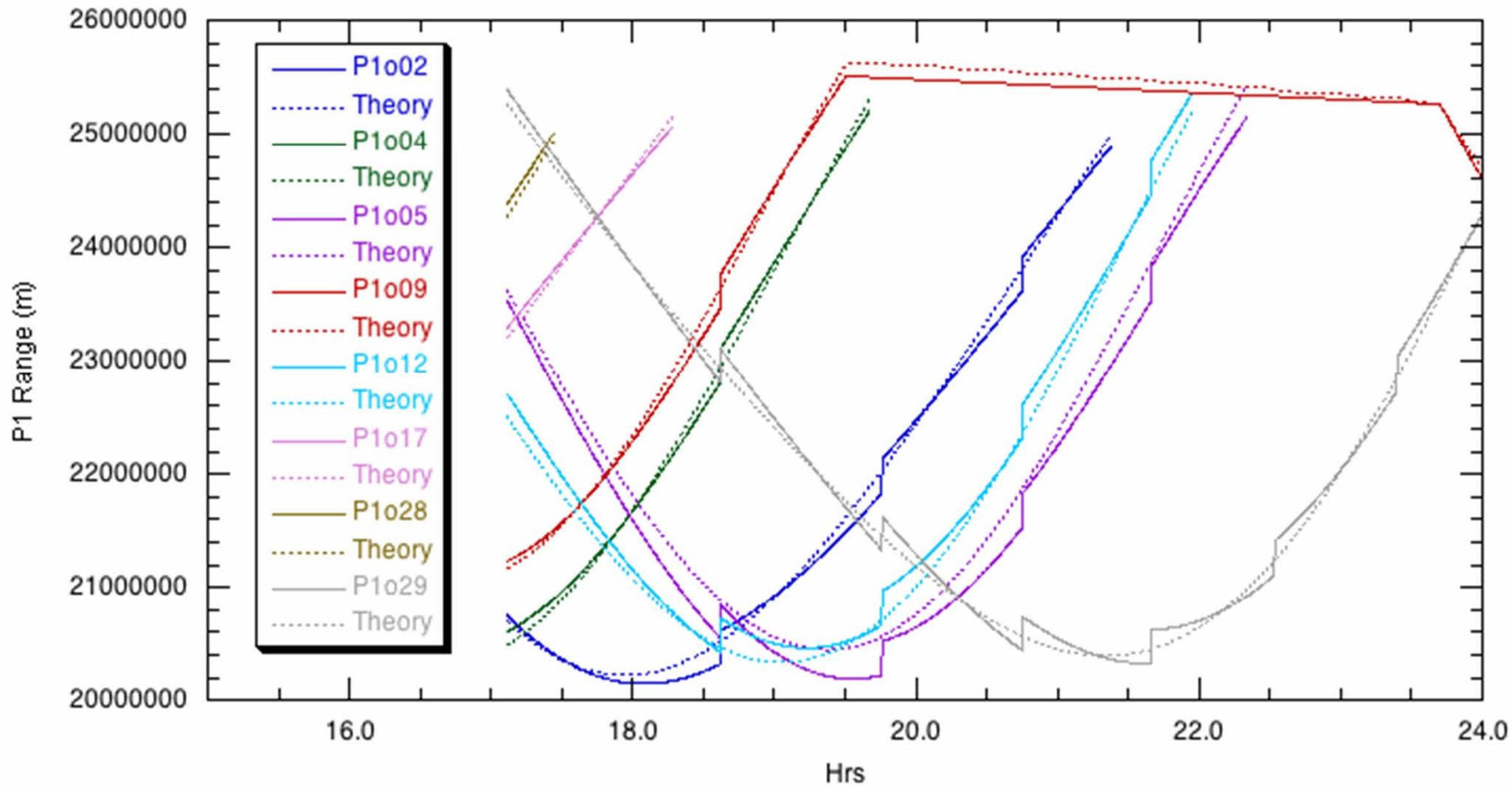
MW-WL Characteristics

- In one-way form as shown the MW-WL does not need to be an integer or constant
- Slope in one-way is common, but notice that both satellites show the same slope.
- If same satellite-pair difference from another station (especially when same brand receiver and antenna) are subtracted from these results then would be an integer (even at this one station, difference is close to integer)
- The MW-WL tells you the difference between the L1 and L2 cycles. To get the individual cycles at L1 and L2 we need another technique.
- There is a formula that gives L1+L2 cycles but it has 10 times the noise of the range data ($\Sigma f/\Delta f$) and generally is not used.
- Discuss more in the processing methods of the course

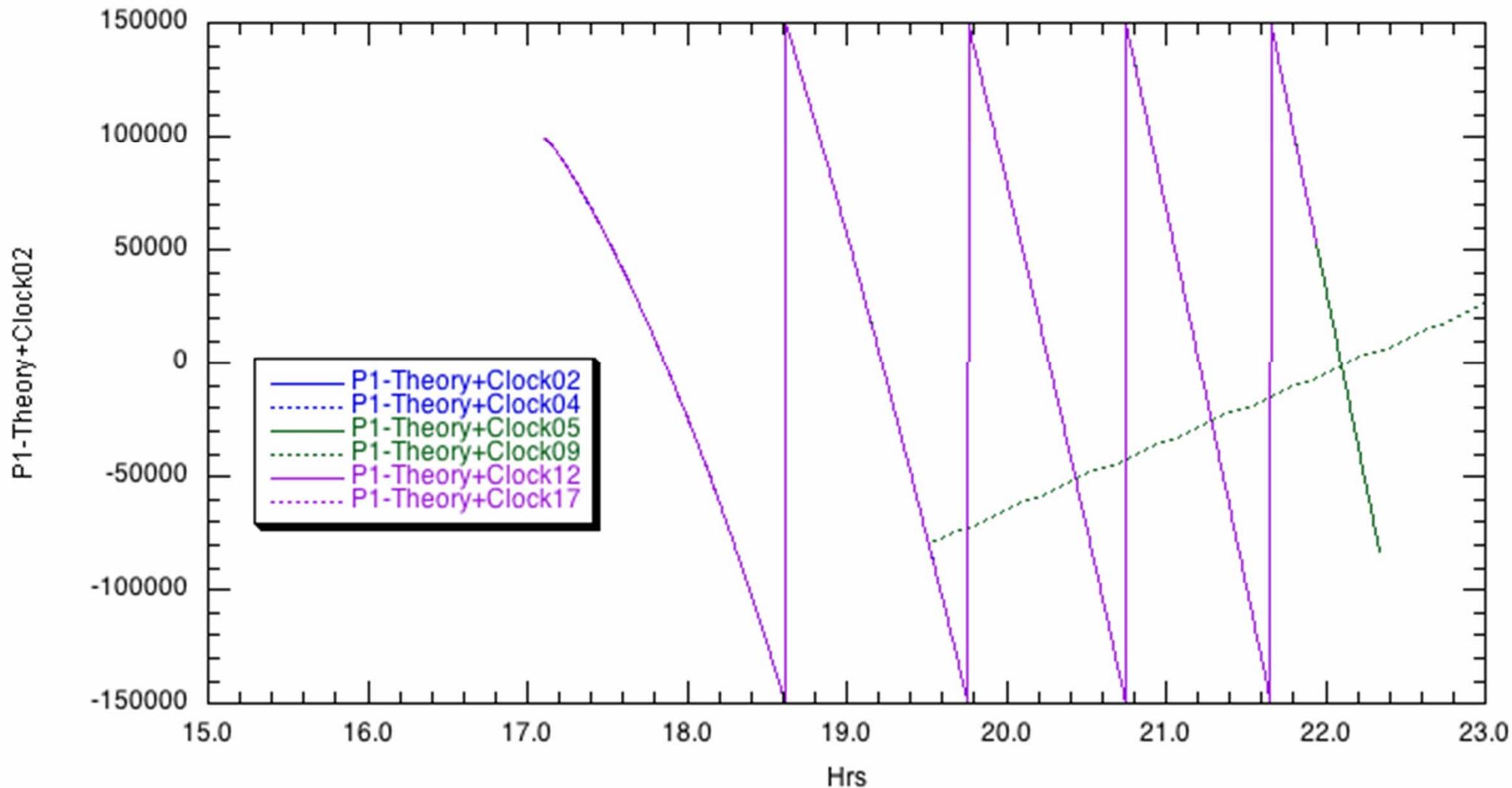
Results from BASE station

- Following figures show similar results to this already shown for the base station site that will be used in homework 2 and 3.
- Results shown here are for 15-seconds over an extended period of time. Homework data will be 1-sec samples over a short time interval.

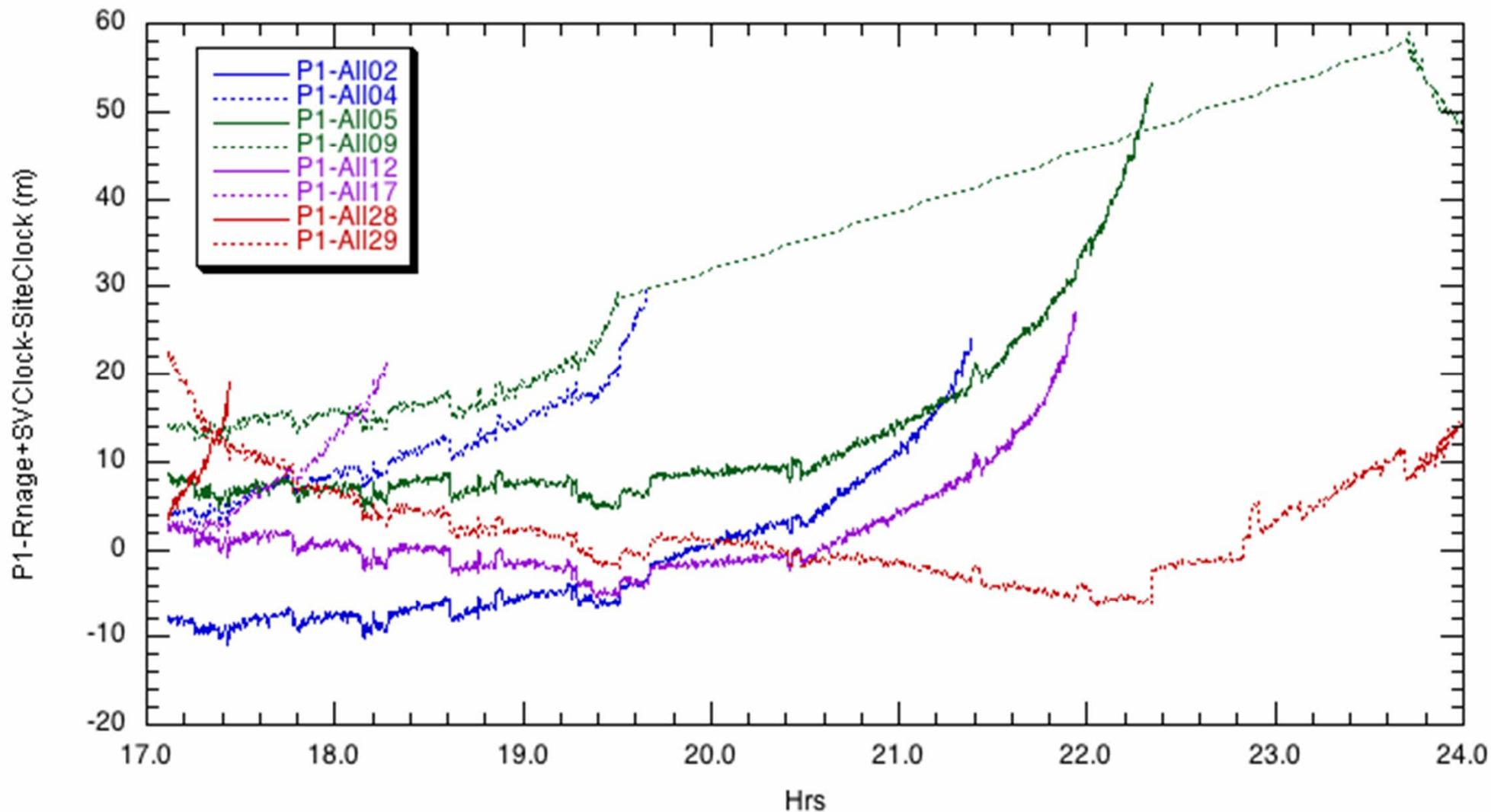
Base 2008 11



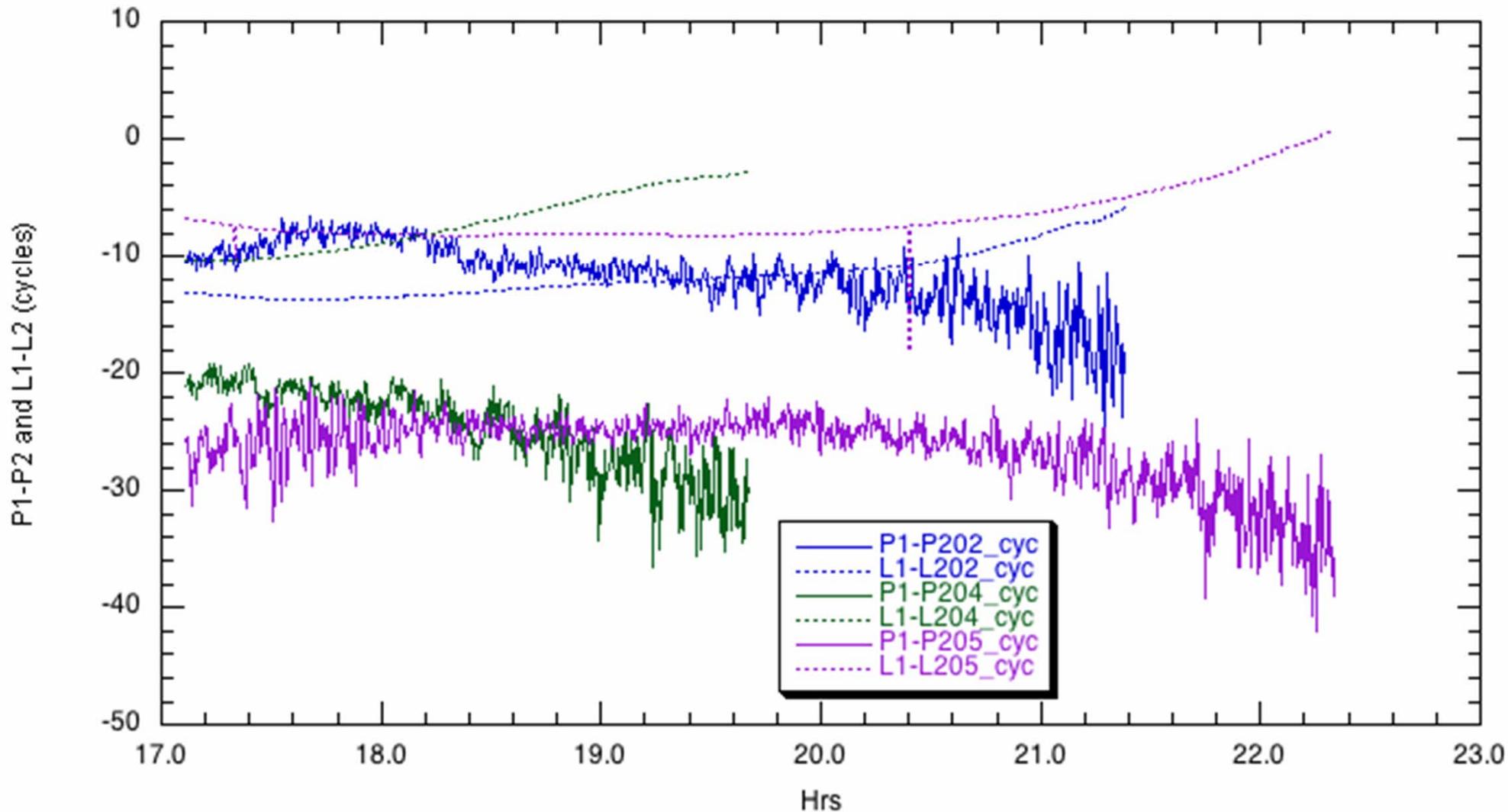
Base 2008 011: Observed P1 – Range + satellite clock (m)



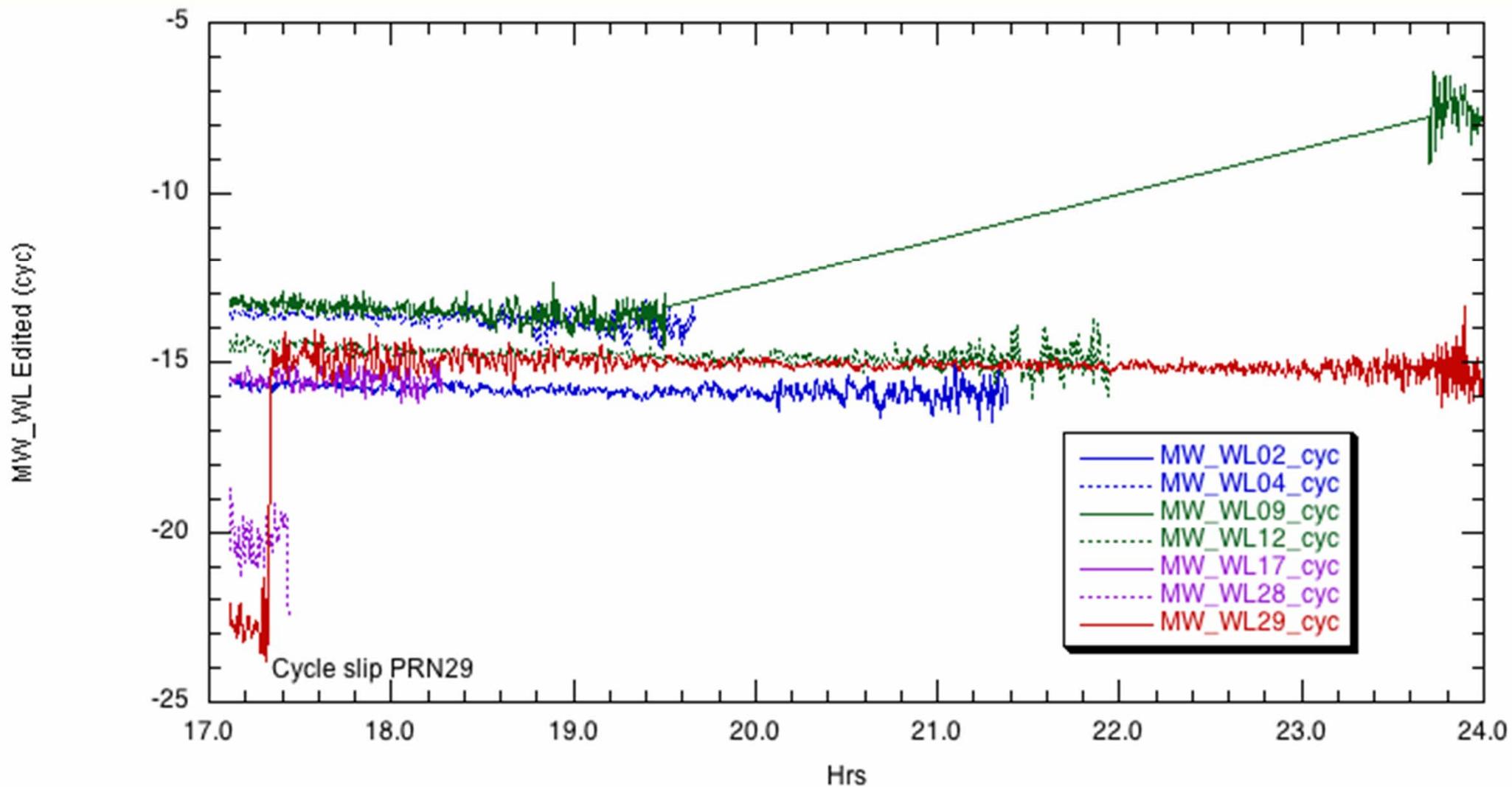
Base 2008 011: P1 Observed – Range + SV clock – Site clock (m)



P1-P2 and L1-L2 (range difference converted to L1 cycles)



MW-WL edited (points deleted)



GPS Data availability

- Over 1000 GPS sites from around the world are available with latencies of 1-hour to a few days.
- The remainder of the lecture we look at these archives starting from the following links:
 - SOPAC <http://sopac.ucsd.edu/>
 - CDDIS <http://cddis.gsfc.nasa.gov/cddis.html>
 - NGS/CORS <http://www.ngs.noaa.gov/CORS/>
 - UNAVCO <http://www.unavco.org/facility/data/data.html>
- There are more sites and many sites show results as well as have data available

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